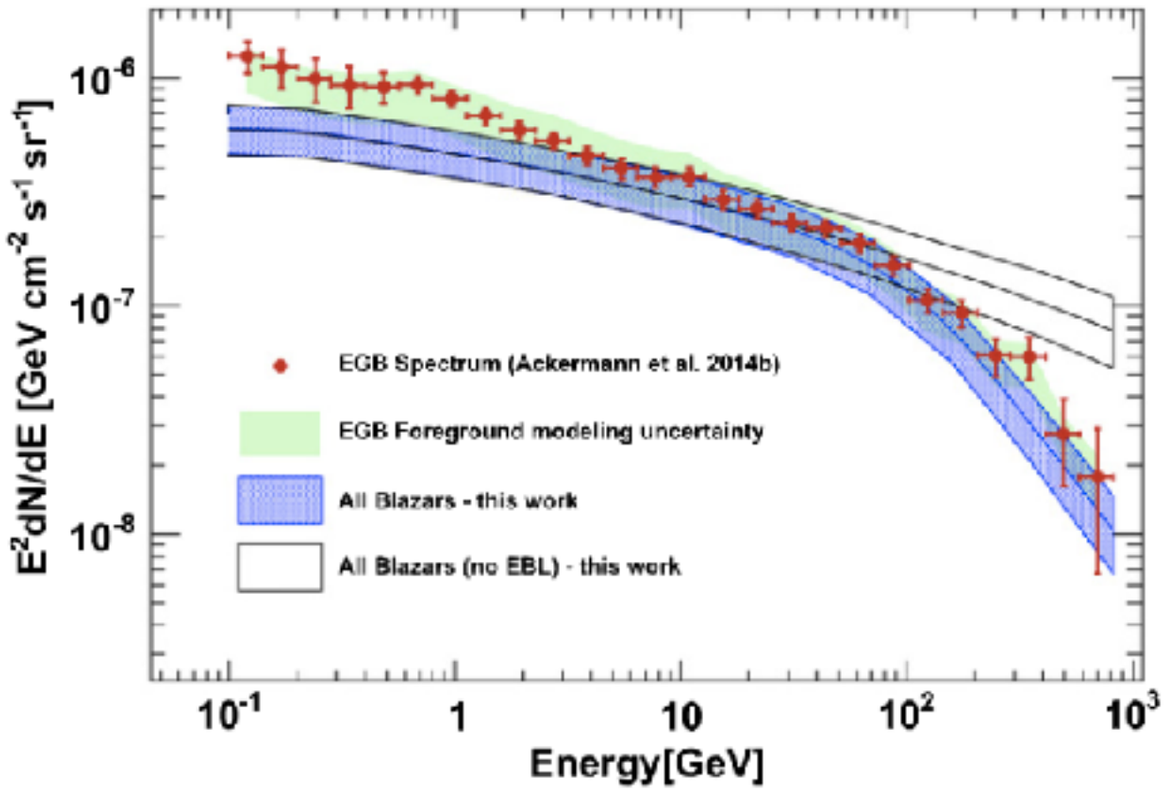
Future Perspective of Cross Correlation of Gamma rays with Large Scale Structures

Masato Shirasaki
National Astronomical Observatory of Japan
Barolo Astroparticle Meeting, 5 Sep. 2018

Mean intensity of EGB

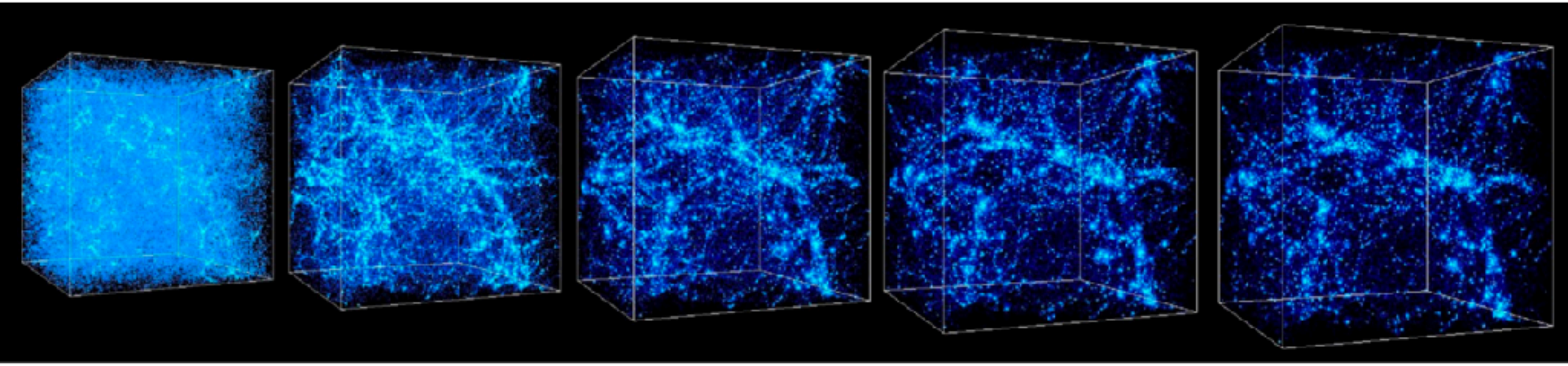
- Mean intensity
  - The shape of energy spectrum can be explained by power-law spectrum with an exponential cut at high energy
  - The amplitude is found to be consistent with the expectation from the sum of unresolved gamma-ray astrophysical sources
- Main contributors came out?



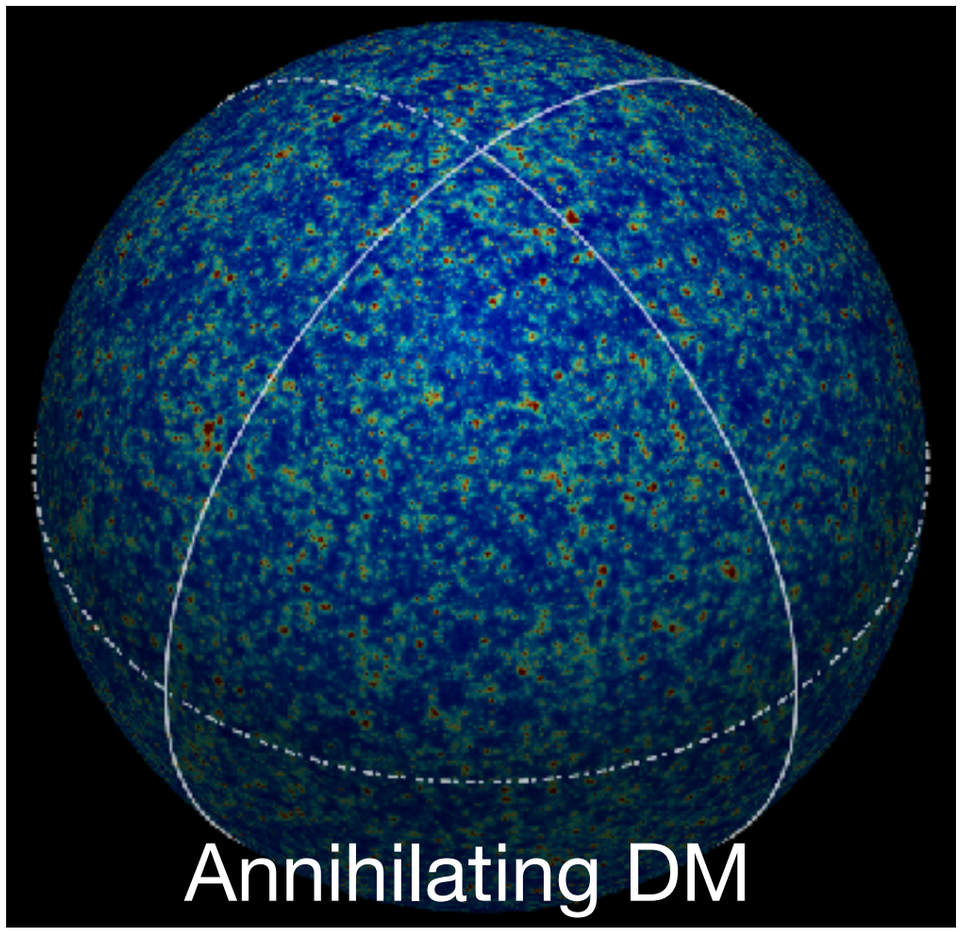
Ajello et al. 2015

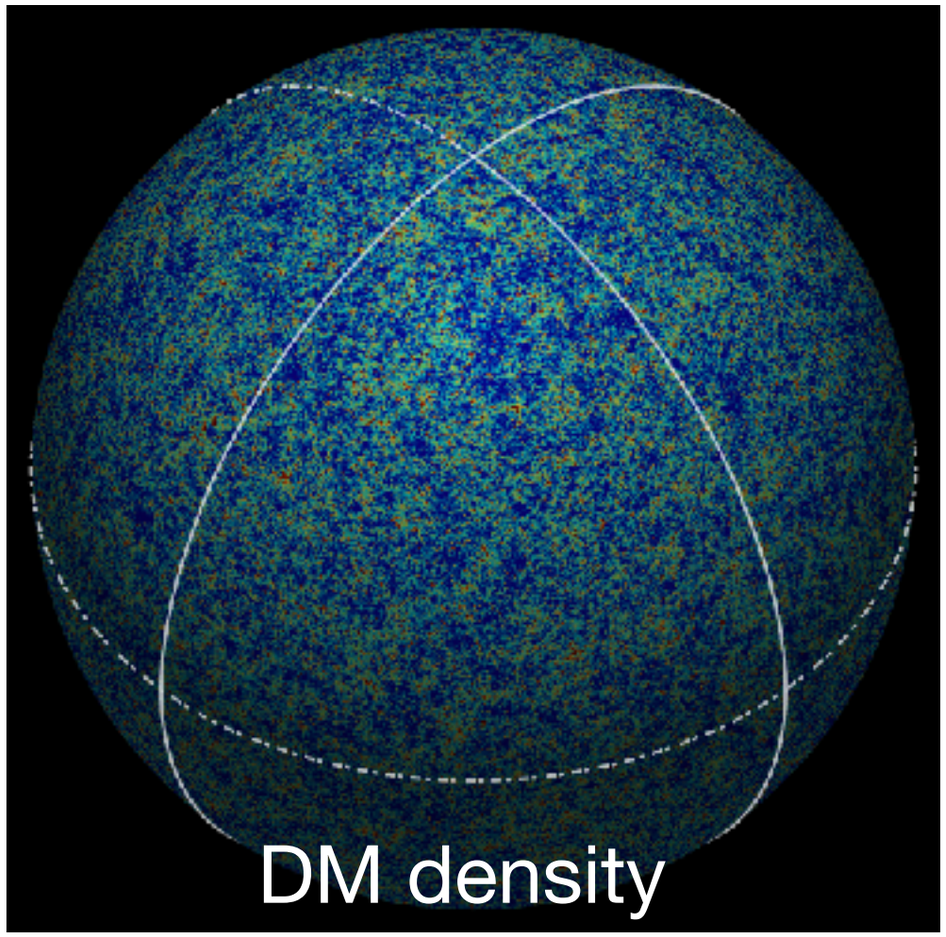
Large scale structures (LSS)

- Tiny gaussian random density fluctuations have grown by gravity
- Non-Linear gravitational growth leads to make many localized clumpy objects, called dark matter halos
- Any gamma-ray sources would reside in dark matter halos



What can we learn from gamma-LSS correlation?

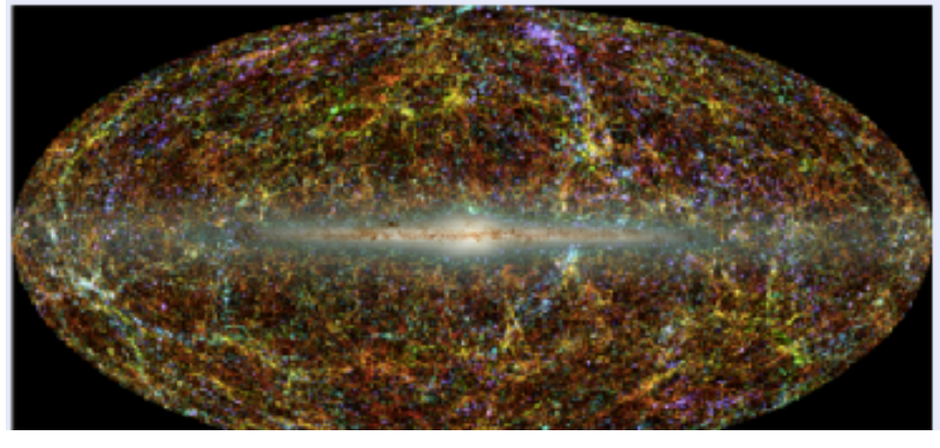


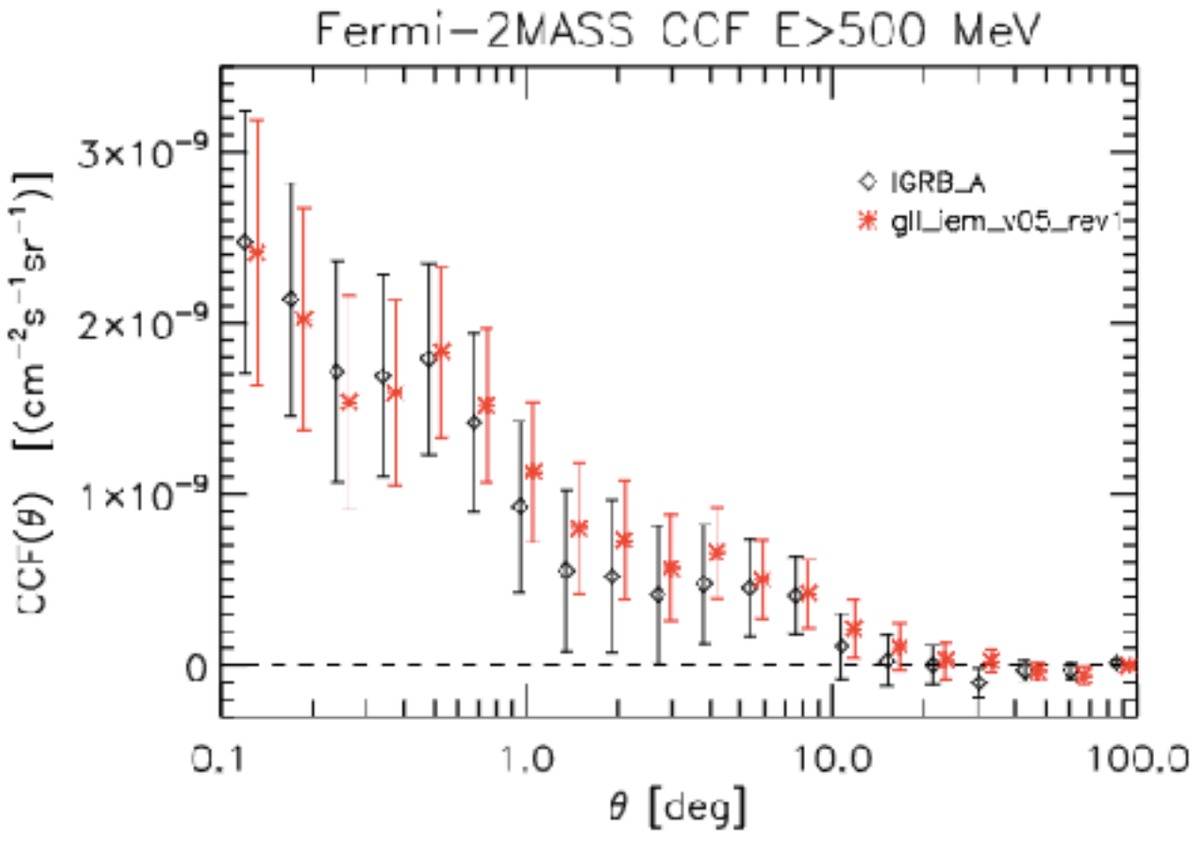


- Nature of dark matter
- Environment of astrophysical gamma-ray sources
  - e.g. Do blazars tend to reside in high-density region, or not?
- Possible decomposition of contributors to EGBs with various LSS tracers
- Advantage : Insensitive to the subtraction of galactic gamma rays in principle

Previous measurements (detected)

- Nearby galaxy (z~0.1)
  - >3.5sigma significance
- CMB lensing (Fornengo et al. 2015)
  - Matter density at z=2-4
  - ~3sigma significance
- Cluster of galaxies at z~0.3 (Branchini et al. 2017)
  - ~4.7sigma significance

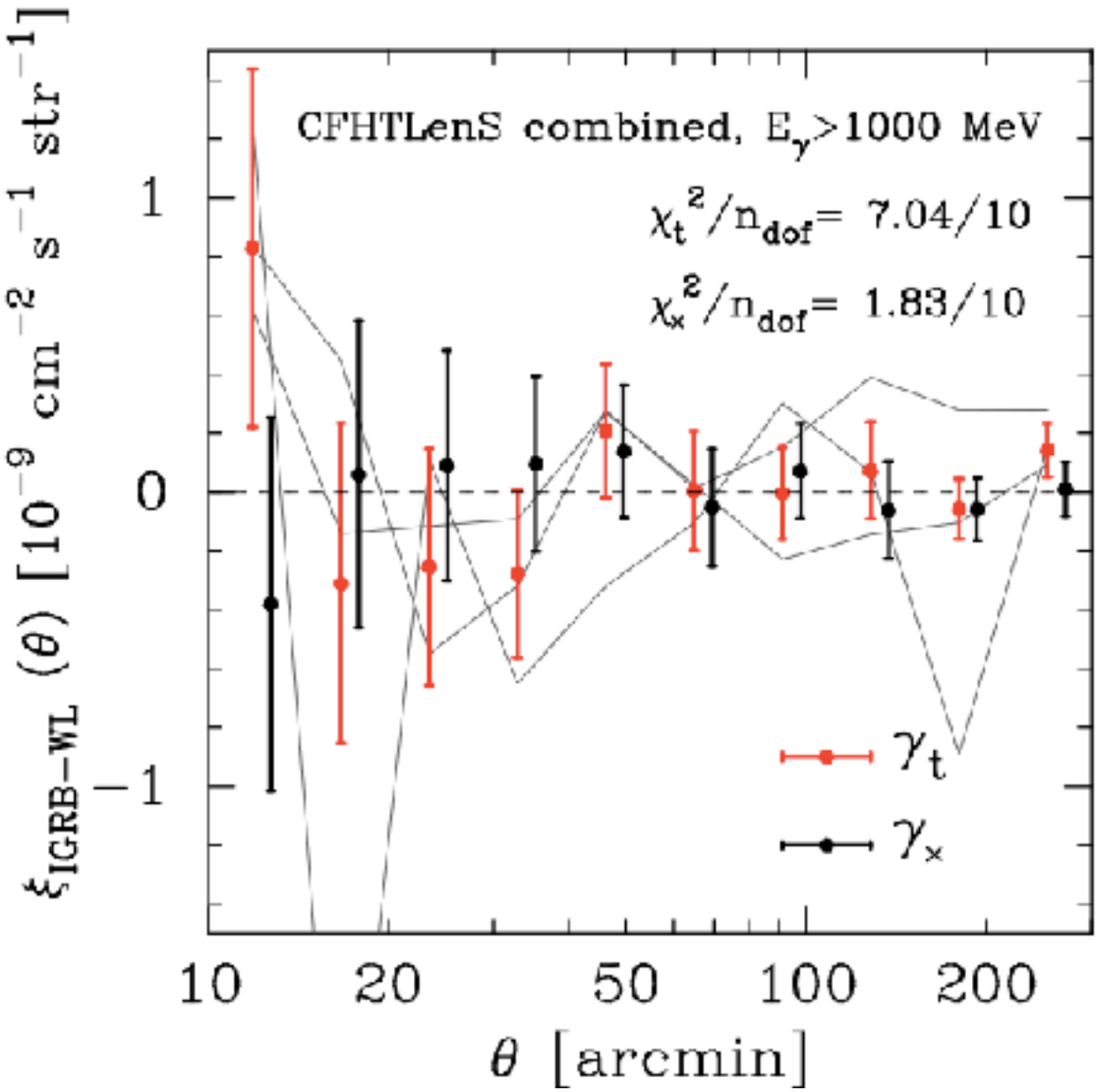




Xia et al. 2015

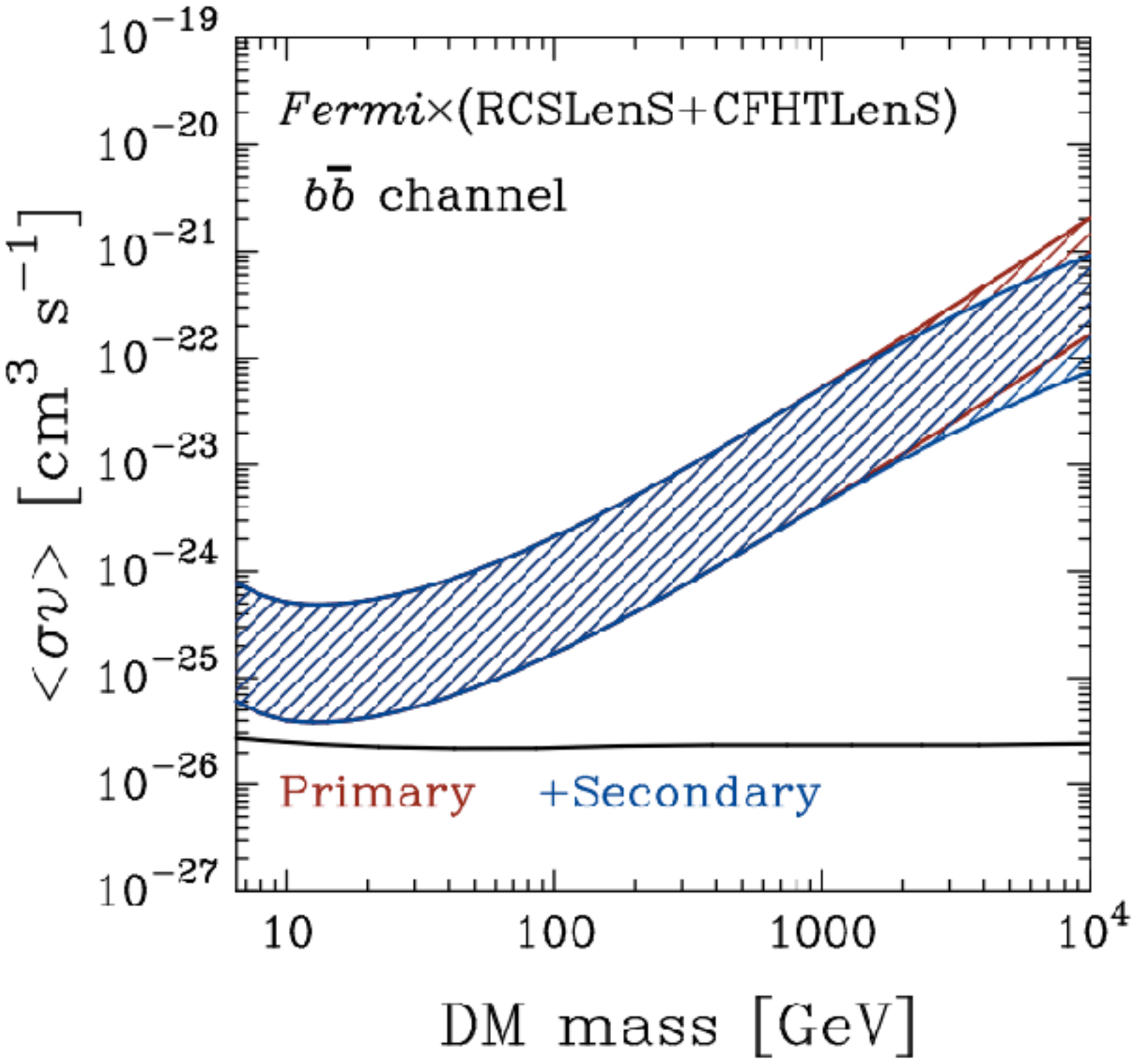
Previous measurements (non-detected)

- Cosmic shear
  - Gravitational lensing effect of distant galaxies at z~0.5-1
- CFHTLenS, RCSLenS, KiDS, HSC
- Survey area is still smaller than 1000 sq.degs



Shirasaki et al 2016

Constraint on dark matter annihilation



conservative upper limit

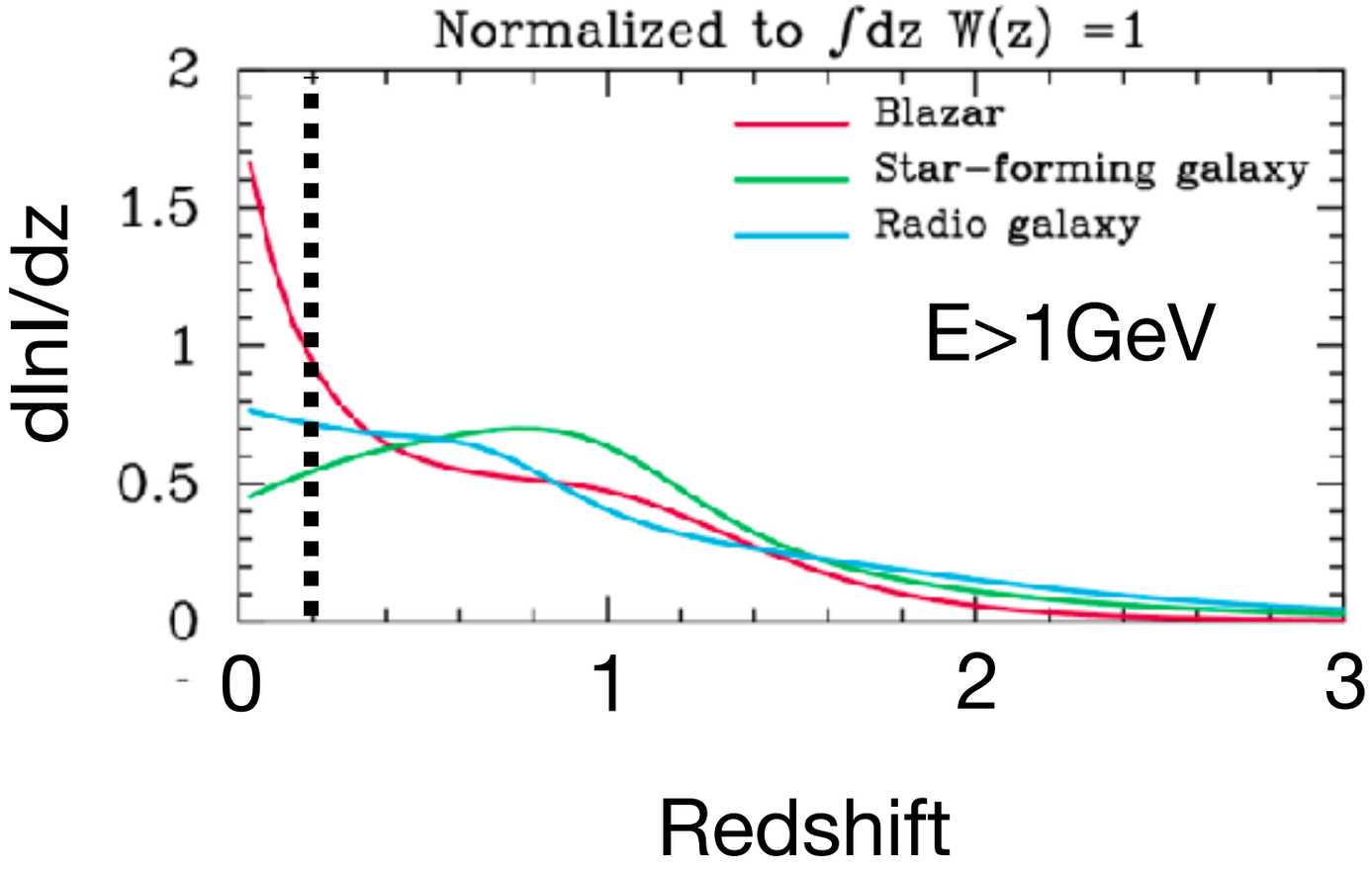
optimistic upper limit

- Based on data over 660 sq.degs (1.5% of the sky)

Shirasaki et al 2016

What’s next

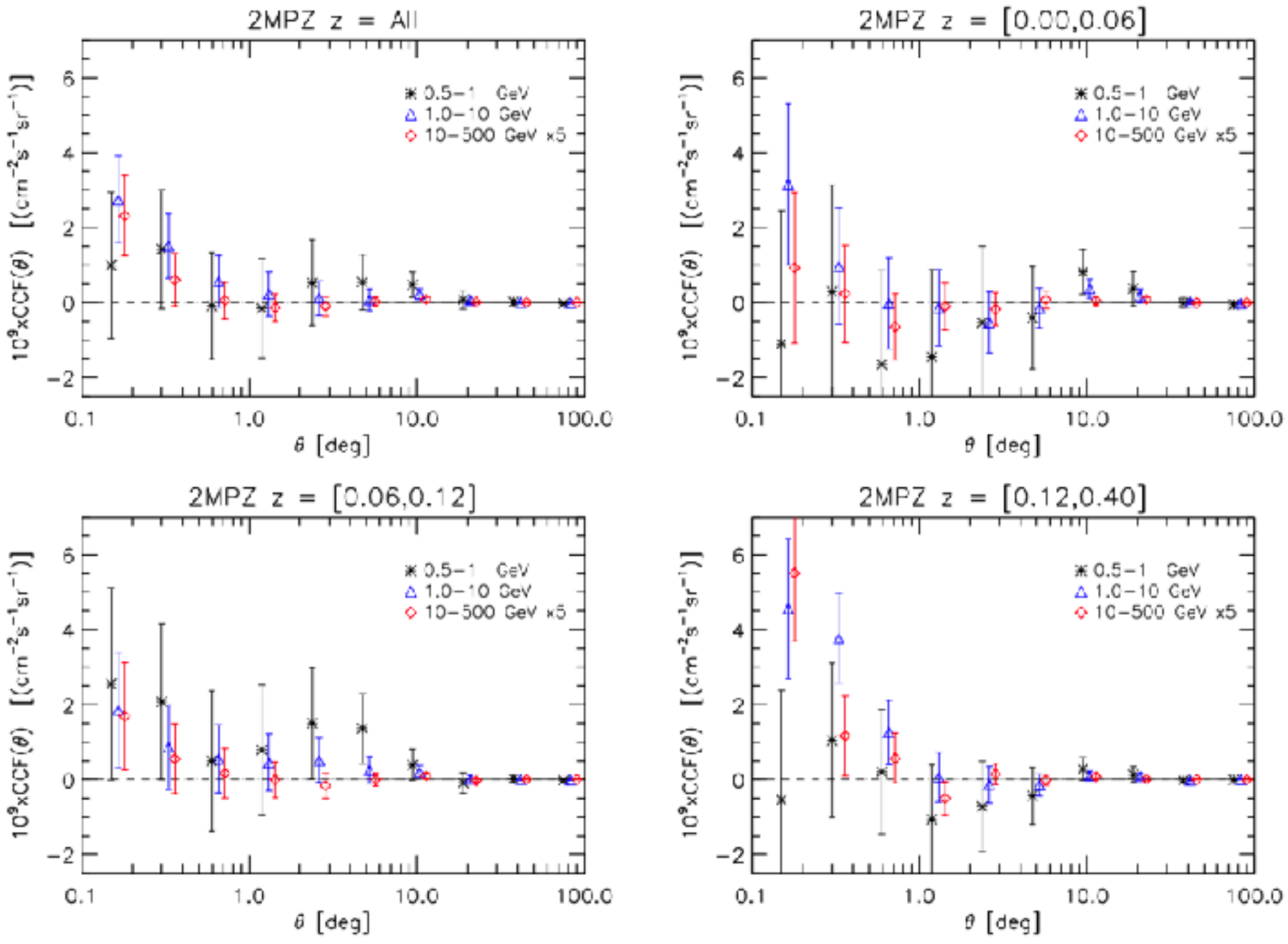
- Data size is growing…
- Tomographic approach (redshift and/or energy)
  - Distinguish extragalactic sources by extracting more info



x LSS tracers at z=0.2

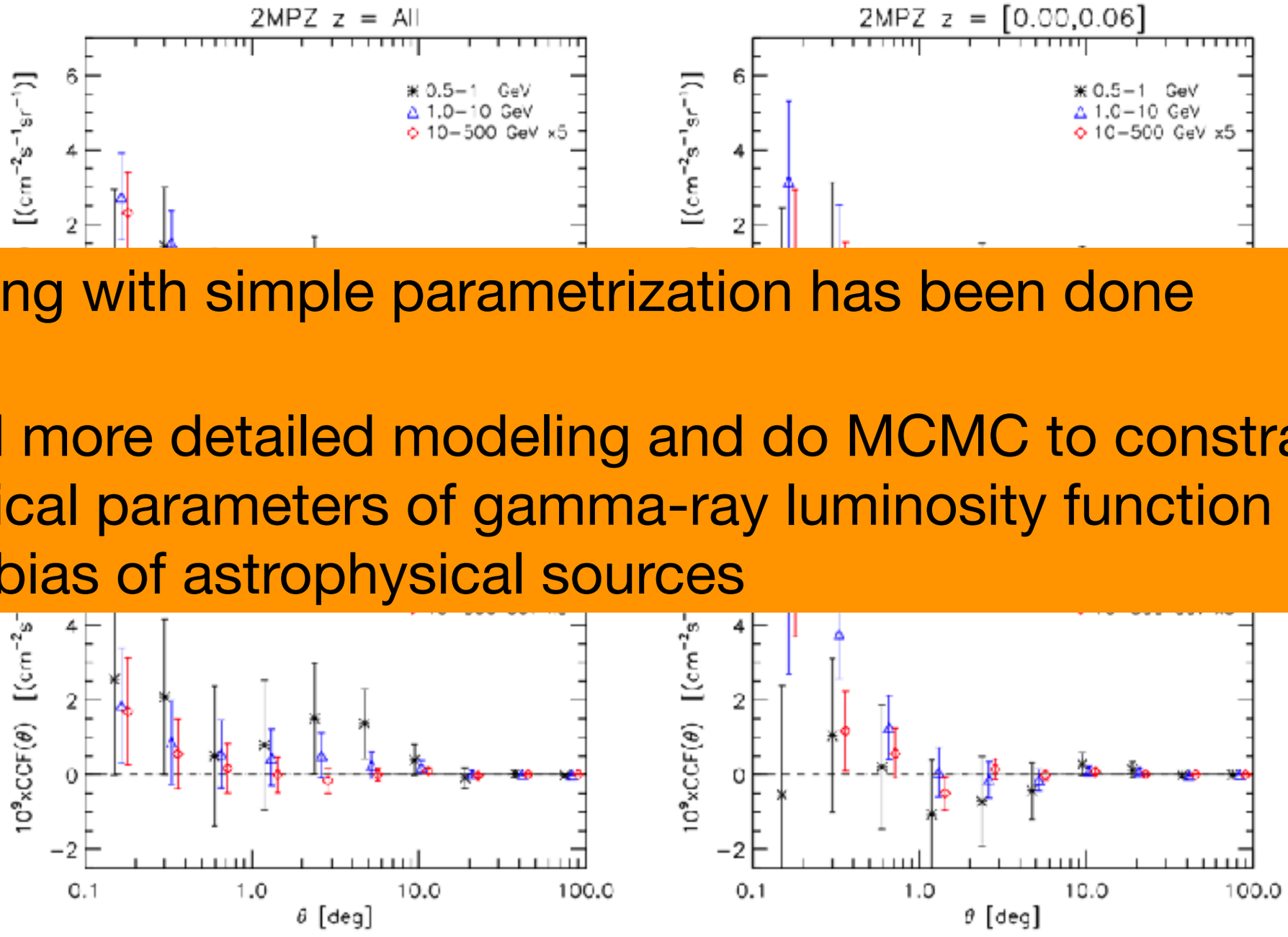
→ Gamma-ray intensity at z=0.2

Tomography in galaxy data



e.g. 2MASS photometric catalog (Cuoco et al 2017)

Tomography in galaxy data

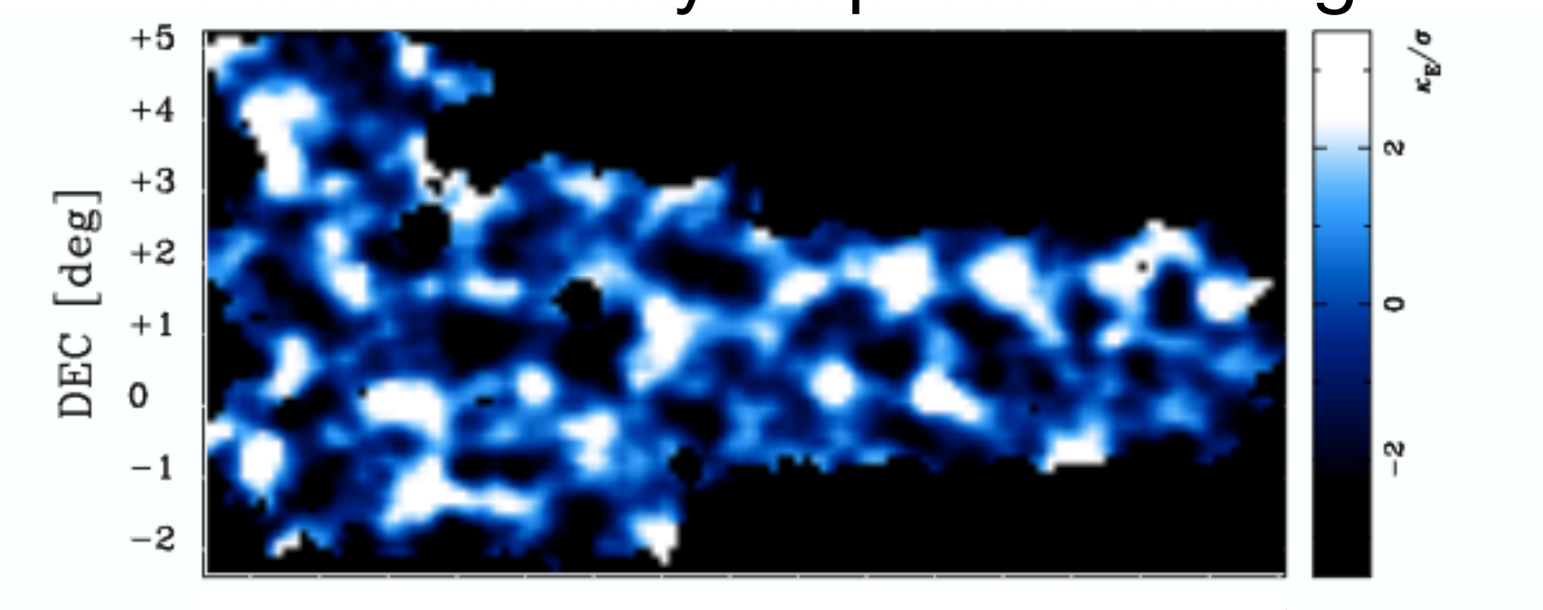


- A fitting with simple parametrization has been done
- Need more detailed modeling and do MCMC to constrain physical parameters of gamma-ray luminosity function and halo bias of astrophysical sources

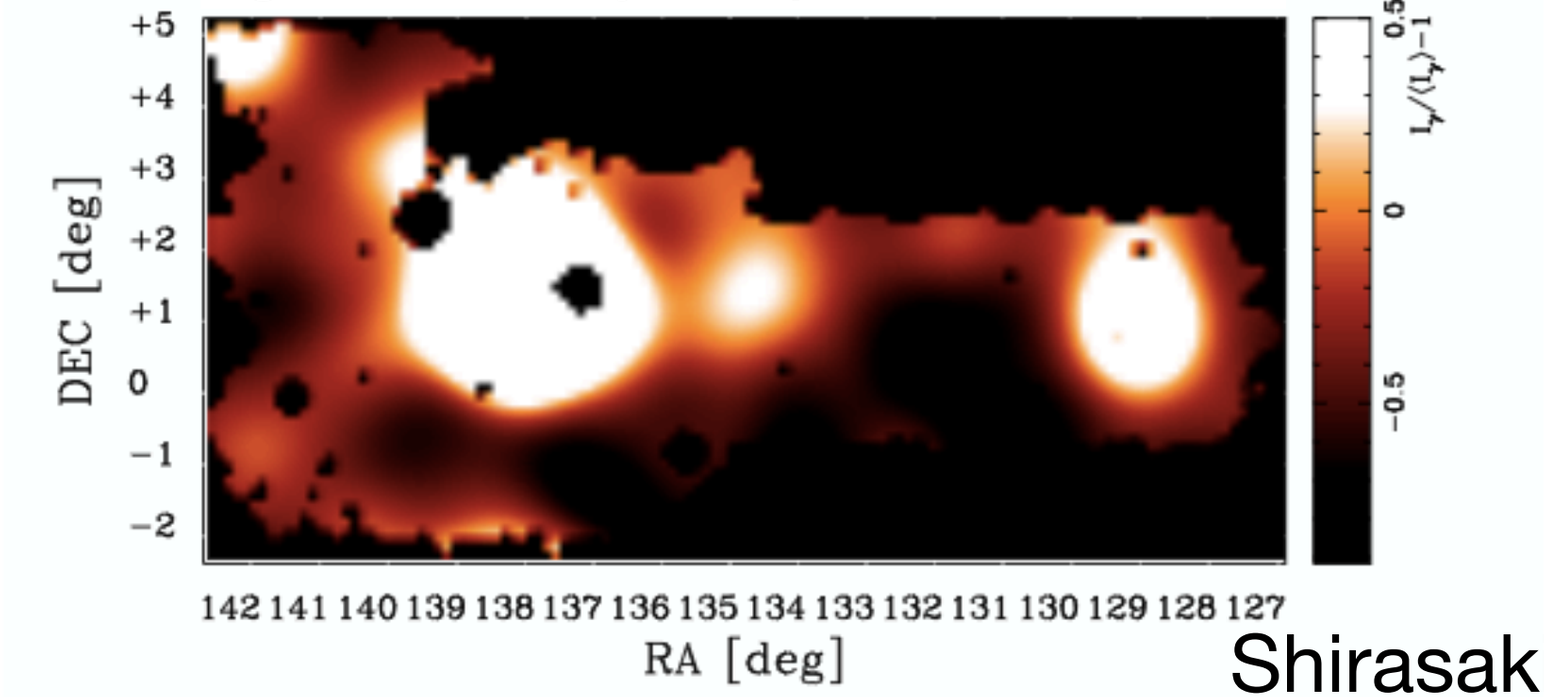
e.g. 2MASS photometric catalog (Cuoco et al 2017)

Tomographic analysis with Subaru HSC* lensing

matter density map from lensing



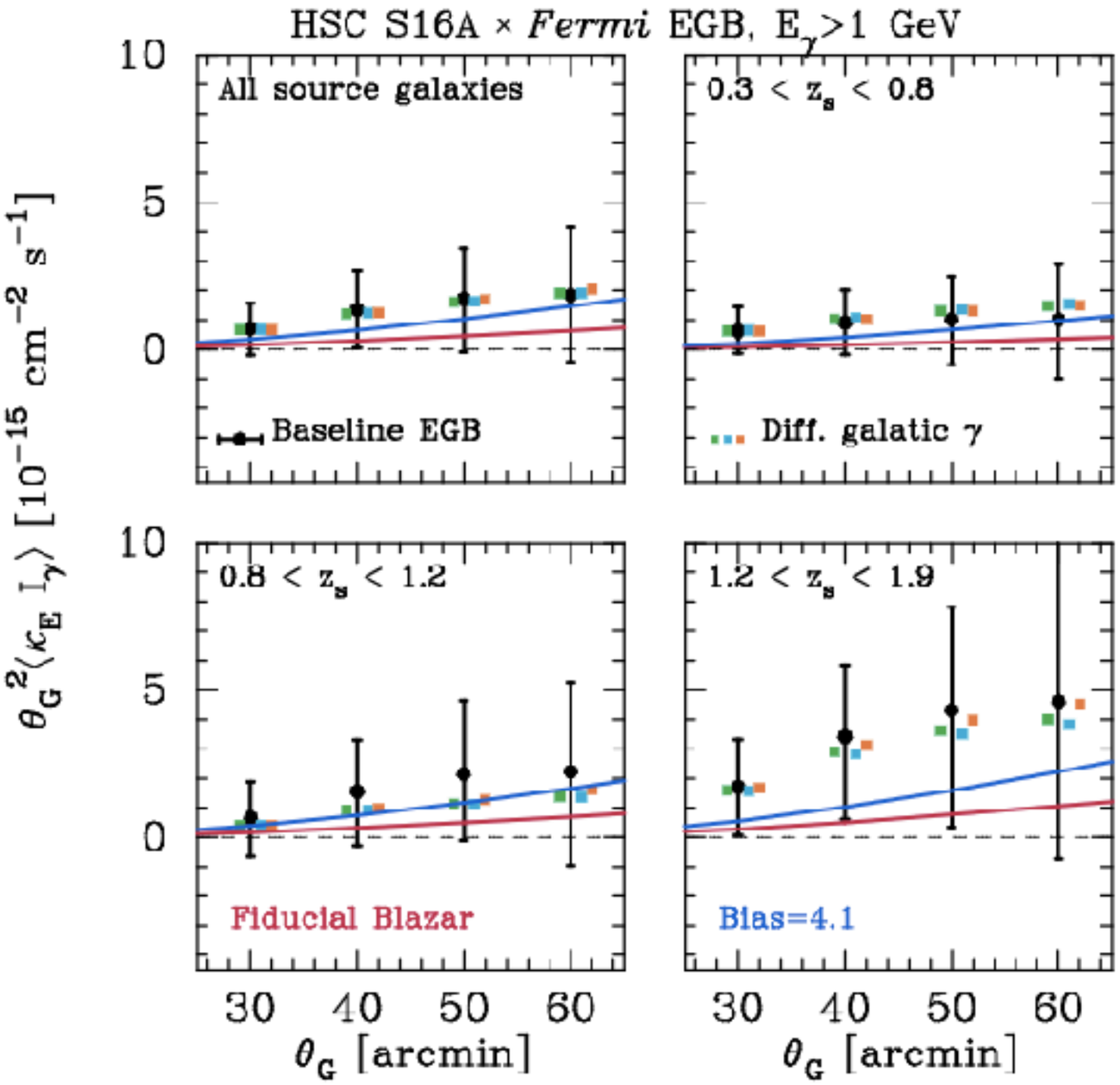
gamma-ray map from Fermi



★google
“hsc ssp”
for details of
HSC survey

Shirasaki et al 2018

Tomographic analysis with Subaru HSC lensing



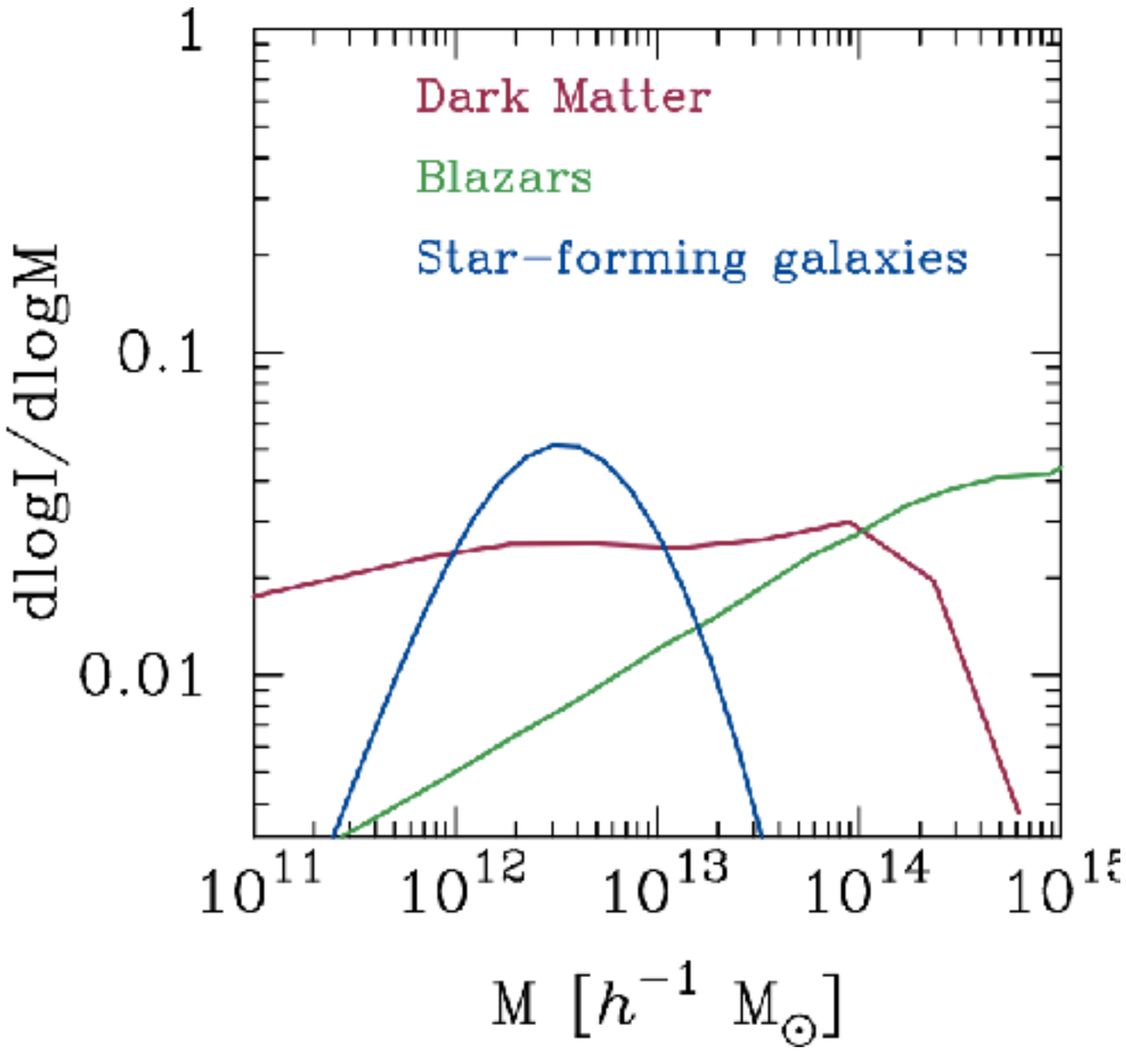
Shirasaki et al 2018

Blazars at z~0.5 may reside in massive clusters?

Just an Idea

- Tomographic approach w.r.t halo mass?
- Two cross correlations will allow us to do
  - Cross correlation with lensing and LSS
    - determine the relation between the luminosity of LSS tracers and halo mass
  - Cross correlation with gamma-ray and LSS
    - relate the gamma-ray intensity and the luminosity of LSS tracers
- Also see Simone et al (arXiv:1808.09225) for tomography with luminosity

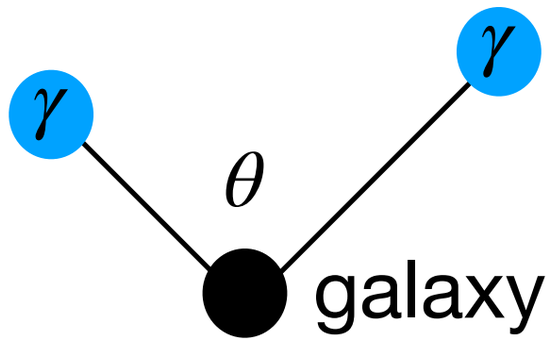
Halo-model prediction



Toward complete understanding of the origin of EGB

Remaining issues

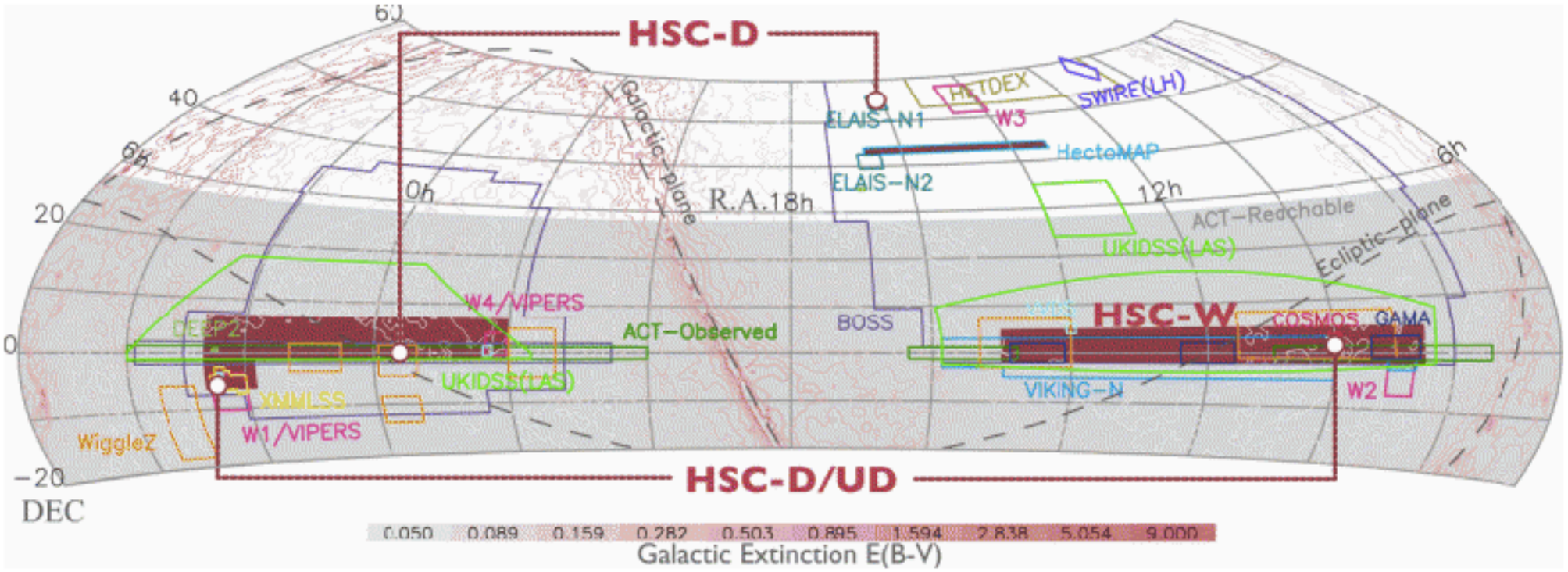
- Use of cosmic background at different wavelength
  - Possible candidates include Infrared, SZ, and X-ray emission
  - Interesting attempt (Feng et al 2017)
- Joint analyses of possible cross correlations
  - Same strategy as modern cosmology. Do care about percent-level effects
- Beyond two-point correlations
  - e.g. Galaxy-gamma-gamma correlation
    - Could be a probe of shape or clumpiness of gamma-ray emission profile in individual halos



Summary

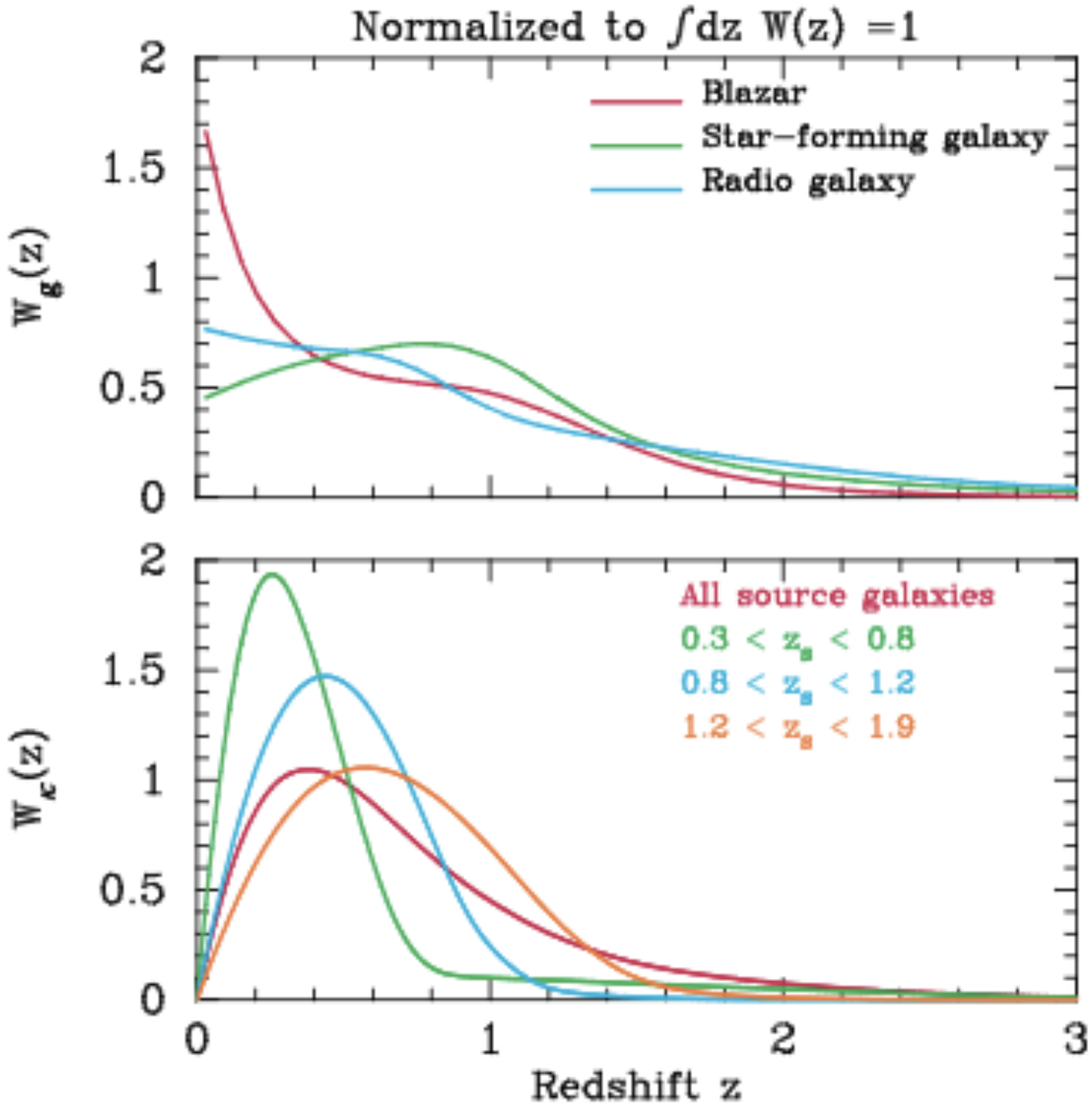
- Cross correlation with Gamma rays and LSS open a new window to relate high-energy photons with matter contents in the universe
- Several LSS tracers show a significant correlation with gamma rays
- Need more data of galaxy lensing (total matter density at z<1)
- Tomographic approach (dividing data by energy or redshift) has been studied
  - Another direction: **tomography with halo mass?**
- Gamma ray can correlate with **cosmic background at other wavelengths**
  - Infrared → star-forming galaxies
  - SZ → Blazar, intracluster medium, extragalactic cosmic rays
  - X ray → AGNs
- **Some interesting frontiers : Higher-order statistics, Joint analysis**

Subaru HSC program



- led by Japan, Taiwan and Princeton University
- Wide layer is designed for weak lensing cosmology
- Known competitors: KiDS (Europe) and DES (US)
- started in 2014. 300 Subaru nights over 5-6 years in total.
    - 1400 sq.degs, source redshift ~ 0.7 and number density of 20 arcmin^{-2}

Tomographic analysis with Subaru HSC lensing



Shirasaki et al 2018